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MEMS 411: Automatic Sewing Pin Dispenser

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Washington University in St. Louis

JAMES MCKELVEY SCHOOL OF ENGINEERING

SP21 MEMS 411 Mechanical Engineering Design Project

Automatic Sewing Pin Dispenser

The aim of our project is to design and embody an automatic pin dispenser for our customer, Melanie, a recreational sewer. Namely, our pin dispenser design aims to address the need for sewers to safely receive and handle dressmaker pins with one hand whilst working with garments. We have identified three main performance goals for an automatic pins dispenser: Store at least 50 pins at a time, produce at least 1 pin every 2-3 seconds, and present at least 90% of all sorted pins in an upward orientation to the user. These performance goals were identified by interviewing our customer and researching current market products. In order to meet these performance goals, we have iterated through a mock-up, an initial prototype, and a final prototype. We have also supplemented and reinforced this physical product development with theoretical engineering models that have provided our team quantitative benchmarks for design performance and safety. Our final automatic pin dispenser design operates with a servo motor wheel that rotates a central pipe container, which is stabilized with a wooden board and four fastened roller wheels. This pipe container intakes, stores, and then sorts pins with magnetic strips. The dispenser then collects these sorted pins with a catcher at the front mouth of the pipe container, and presents the pins conveniently for the sewer to grab with two fingers. Our dispenser meets all of the performance goals, and therefore serves as a powerful tool for sewers who hope to simultaneously handle garments and dressmaker pins effectively.

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1 Introduction

Sewing pins are a useful tool in sewing however at times they can be difficult to handle. Being a pin there isn't any easy way to keep them upright on their own and picking them off a table can be annoying. That is why we are developing a device that can sort pins of any orientation and present them straight towards a sewist. The pins that we will focus around are the low-profile small headed types that are common for most home applications. Our device will be targeting primarily home sewists so we will be making something that can fit on a table and is relatively inexpensive.

2 Problem Understanding

2.1 Existing Devices

Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo inventore veritatis et quasi architecto beatae vitae dicta sunt explicabo.

2.1.1 Existing Device #1: Pintastic Automatic Pin Dispenser



Figure 1: Pintastic Automatic Pin Dispenser (Source: June Tailor)

Link: <https://www.amazon.com/June-Tailor-JT230-Pintastic-Automatic/dp/B004W8WFNG>

Description: The pintastic automatic pin dispenser is a portable battery power pin dispenser that can accept a wide variety of pins and present them to the user. This specific design is powered by four AA batteries and is 8 x 11 x 6 inches which makes it small enough to fit on most workspaces.

2.1.2 Existing Device #2: Pin Secret Magnetic Bobby Pin Dispenser / Holder -



Figure 2: Pin Secret Magnetic Bobby Pin Dispenser / Holder (Source:Suns Out Beauty Store)

Link: <https://www.amazon.com/June-Tailor-JT230-Pintastic-Automatic/dp/B004W8WFNG>

Description: The Magnetic Bobby Pin Dispenser is a device that uses magnets to sort and hold pins. Despite its name the device can be used for sewing pins. The device has a top magnetic that can attract and present any metal pins to the user. Its light weight and small size makes it easy to carry and use in a variety of places.

2.1.3 Existing Device #3: Grabbit Magnetic Sewing Pincushion



Figure 3: Grabbit Magnetic Sewing Pincushion (Source:Grabbit)

Link: https://www.amazon.com/Grabbit-Magnetic-Sewing-Pincushion-Plastic/dp/B000YZ7P9K/ref=sr_1_2?dchild=1&keywords=magnetic+straight+pin+holder&qid=1612833057&sr=8-2

Description: The Grabbit Magentic sewing Pincushion is similar to the pin secret device in that it relies on a magnet to hold the pins. How it works is that there is a magnet at the bottom of the bowl which attracts the metal part of the sewing pin. The result is that the sharp end stays down while the head pokes up making it easy to grab.

2.2 Patents

2.2.1 System, method, and apparatus for repurposing currency (US20180108199A1)

This patent describes a method to re-purpose metal coins, termed currency, including the following actions: Discharging processed mixed coins into a coin bin, receiving a first request for a number of or value of coins of a first denomination from an authorized person, outputting those mixed coins onto a conveyor responsive to the request, conveying the coins output from the bin to the processing machine for re-purposing, and discharging the coins of the preferred denomination to a secure cassette. The actions of outputting, conveying, and discharging coins are continued until the value of coins of the first denomination have been discharged to the secure cassette.

Though our device will need to also orient the output metal parts (pins) in a certain way, the sorting and storage methods used by the coin machine may be of use in our system architecture. Images of the coin machine construction and system architecture are shown in Figures 4 and 5, respectively.

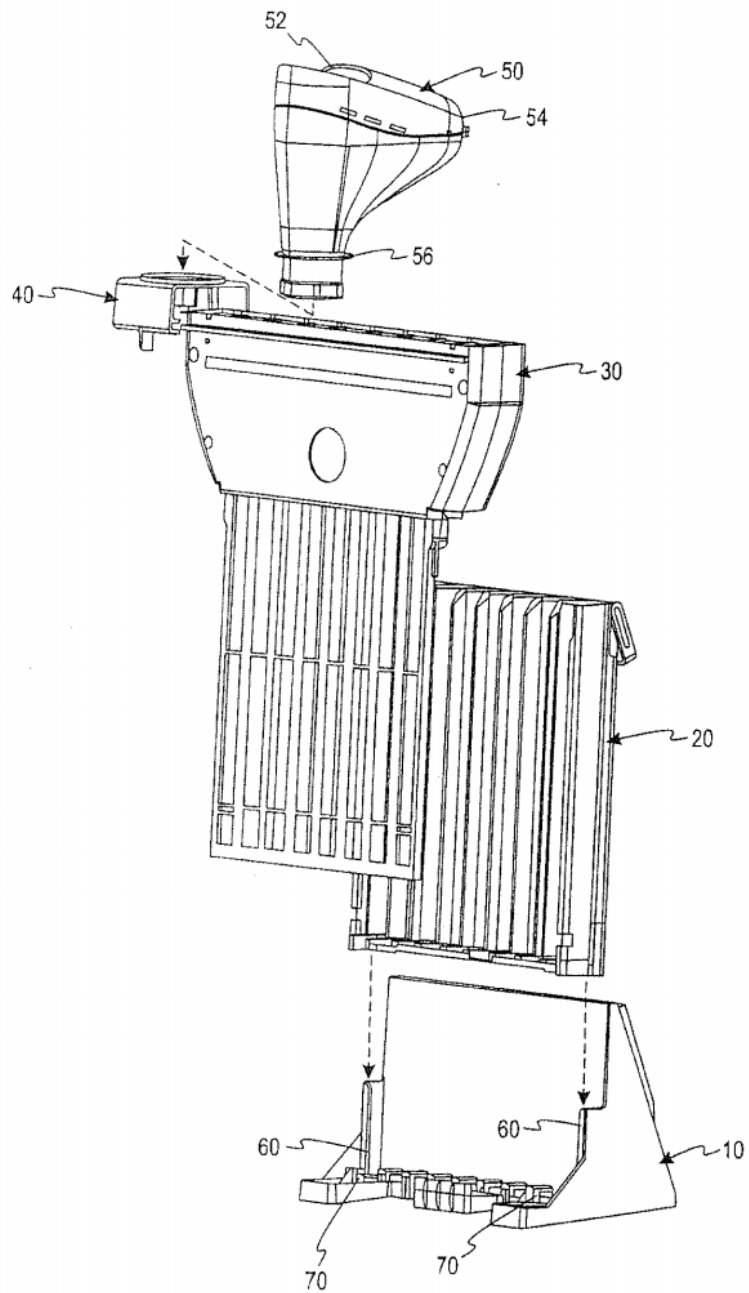


Figure 4: Patent image for coin machine construction

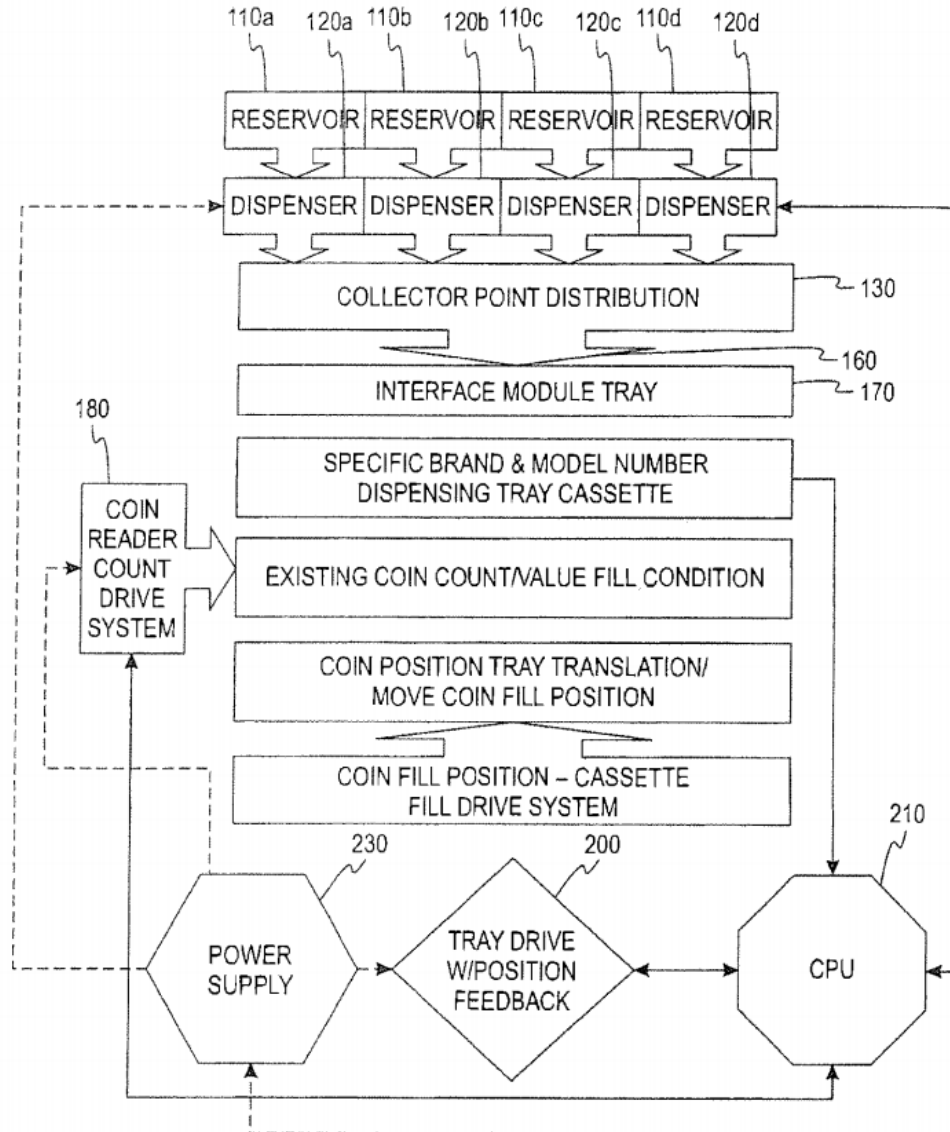


Figure 5: Patent image for coin machine system architecture

2.2.2 Pin dispensing system and method (US20120181299A1)

This patent describes a pin dispensing apparatus. This design includes a dispenser configured to present a pin to a user, a transfer member that transfer the pin to a dispenser, and a delivery mechanism configured to provide the pin to the transfer member.

This patent mostly achieves what our team hopes to with our pin dispenser design, though the one drawback is that it cannot handle dressmaker pins. Dressmaker pins have tiny heads, making them a difficult object to orient and convey to a dispenser. Figure 6 shows an isometric view of the patent dispenser design below.

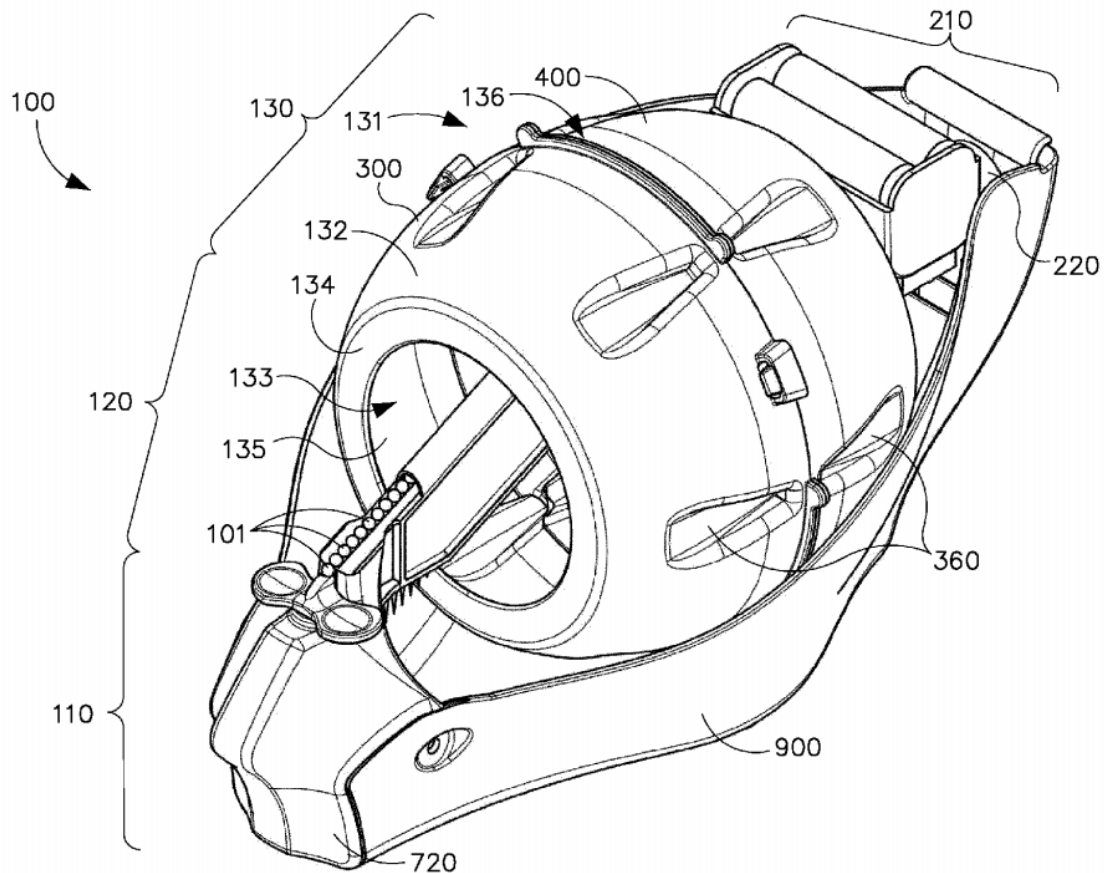


Figure 6: Patent Image for pin dispenser

2.3 Codes & Standards

2.3.1 Sewing machines needles - Fitting dimensions - Tolerances and combinations (ISO 8239)

ISO 8239 specifies the fitting dimensions of needles and needle holders. It defines general terms for sewing machine needles and specifies the tolerances for their fit in the needle holder. In addition to the ranges of dimensions for the nominal shank diameter and the length from butt to eye, ISO 8239 also indicates the preferred combinations of these two dimensions. In order to ensure the interchangeability and to reduce the variety of needles these should serve as a guide when designing new sewing machines and/or sewing machine needles.

2.3.2 Industrial sewing machine - Safety requirements for sewing machines, units and systems (ISO 10821)

ISO 10821 identifies hazards and specifies safety requirements applicable to sewing machines, sewing units and sewing systems designed for professional (industrial, commercial or laboratory)

use in industries including the clothing and footwear, leather goods, shirts and blousery, hosiery and knitwear, lingerie, glove, upholstery and packaging industries, and in shoe repair. The use of such machines in other industries could give rise to hazards not considered. It is not applicable to shoe bottom stitching machines, large shuttle embroidery machines in accordance with ISO 11111 or household sewing machines in accordance with IEC 60335-2-28.

2.4 User Needs

In order to research which user needs our team needs to meet in the course of designing the pin dispenser, we interview a customer, Melanie Heckman. Melanie sews recreationally, and uses dressmaker pins in the process. She approached our class with the desire to create a dispenser that could sort and produce these pins quickly. This sort of device would streamline her sewing workflow and make sewing more safe.

2.4.1 Customer Interview

Interviewee: Melanie Heckman

Location: Zoom Meeting

Date: February 2nd, 2021

Setting: All three of the sewing pin dispenser groups, including ours, joined Melanie in a group call on Zoom for about 30 minutes. Melanie showed us her sewing setup and methods for working and handling the pins. We then asked her questions regarding potential concerns for the sewing pin dispenser design, as well as her longstanding sewing needs that we hope to address.

Interview Notes:

Is there any specific size that you use? Should it be able to handle multiple sizes?

- Melanie uses dress-maker's pins (no big round head) The dimensions for the pins are in the range of: 1-1.5 inch length, 0.4-0.6 mm diameter. The brand is Dritz, and sold at Joann's fabrics.

What is the maximum volume of pins that you carry at one time?

- Her current storage box carries about 300 pins, though she doesn't use nearly that many in one sitting.

How rapidly do you want the dispenser to produce pins?

- Not slower than one per 2-3 seconds. So, our operational dispenser window should be under 10 seconds (she said 10 seconds would be the limit for her), with a faster dispense rate rated higher for efficiency. She normally lays a bunch on the table or puts them in her mouth, since she has to focus and use numerous pins in succession when sewing a garment. Essentially, when one pin is taken, she wants another immediately produced so that she can work efficiently and not lose track of her place sewing and preparing the garment.

At which orientation would you like to pick the pins up?

- She wants a vertical, or upward, orientation with the head pointing up. This is for ergonomic and safety reasons.

How loud is your sewing machine?

- It vibrates the sewing tabletop and is fairly loud. As a result, the pins need to be secured so that they don't fall out when presented to her.

Are you concerned with how it looks?

- The size of it doesn't matter. Yet, it looked like she wasn't working with that much room on her sewing table, so the smaller the better. Also, she would like it to be light enough so that she can pick it up easily. She also said that the dispenser does not have to be aesthetic.

Are there quality restrictions for the pins?

- You cannot bend or dull the pins, or they will mess up the garment/sewing equipment. This means that the dispenser should not handle the pins too rough, as they can bend easily due to their thin shape.

In which ways would you envision feeding the dispenser new pins?

- There are two methods: She can dump a whole box in at once, or place a small amount at a time while working. As a result, she said that if there is a way to be a receiver next to the dispenser that would be great.

How do you hold the pins?

- She grabs pins between thumb and forefinger, right below the head. Understandably, the ease of picking up the pins will be a big aspect of her perceived quality of the device, since that is the primary operation that she needs integrated into her sewing workflow. Ideally, she wants to pick up the pins at or near table-top height.

Is your working surface resistant to wear/stains?

- Rubber feet are preferred so that they don't damage tabletops. Also, rubber feet would stabilize the dispenser and absorb vibration produced by the sewing machine. Furthermore, rubber feet would insulate thermal conduction coming from an electrical source within the dispenser. This is beneficial for Melanie, as her wooden table would avoid discoloration from excess heat.

Any storage needs?

- She prefers that there be some lid or box to hold it in storage, also to make sure that pins don't fall out when not using the dispenser. Also, it may be in storage for long periods of time between sewing sessions, so catching dust would be another possibility. Using a container would preserve the dispenser and keep it clean. Placing a handle on the container would be a good idea if the dispenser is heavy, for ease of transport.

Any maintenance/excess material concerns?

- The dispenser may need to be able to handle and ideally separate out extra strands of fabric that are stuck to the needle, as this is a pretty common occurrence when sewing. As for maintenance (taking the dispenser apart to take out extra fibers), she is comfortable with taking the dispenser apart with screws, as long as there is a diagram to take it apart then. Therefore, we should make an operational manual.

Do you have a failure margin for sorting and presenting pins in the right orientation?

- Though she currently stabs herself approximately three times for every 150 pins, any sort of failure rate would not be good since she will poke herself if grabbing for the sharp end.

Any material notes?

- The pins are nickel-plated brass, so they are magnetic.

Do you mind if the dispenser is powered by electricity?

- Batteries or outlet plugs are fine with her. We should just pay attention to weight if we use a battery pack or large outlet plug.

2.4.2 Interpreted User Needs

After interviewing the customer, our team extracted and compiled the main user needs that should be addressed in the pin dispenser design. These Interpreted Customer Needs are presented in Table 1 below.

Table 1: Interpreted Customer Needs

Need Number	Need	Importance
1	The Dispenser produces pins with the head facing upward	5
2	The Dispenser produces pins quickly	4
3	The Dispenser sorts the pins	5
4	The Dispenser absorbs vibration	3
5	The Dispenser handles the pins gently	5
6	The Dispenser produces pins at a table-top height	4
7	The Dispenser is light enough to pick up easily	4
8	The Dispenser has a container for storage and transport	3
9	The Dispenser separates pins from excess fabric/thread	4
10	The Dispenser takes multiple pins in at a time	5
11	The Dispenser dissipates heat to protect tabletop	3
12	The Dispenser is stable	5
13	The Dispenser can be taken apart and fixed	4
14	The Dispenser is compact	3
15	The Dispenser secures pins that are dispensed	5

In Table 1, the most important needs are highlighted with a score of 5 in the Importance category, and then the supplemental needs are ranked with 3's and 4's. Our group will need to address the 5-ranked needs first in our design, and then address and delegate the others that are met in the latter stages of our prototyping process.

2.5 Design Metrics

Based on the interpreted user needs highlighted in the previous subsection, we have compiled a list of design metrics in Table 2 below. Note that there may be countless design metrics that surface in the future for our team when we begin to prototype, but these are at least relevant to our customer interview and preliminary research for existing devices and codes and standards.

Table 2: Target Specifications

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	7	Total weight	kg	10	1
2	14	Total volume	cm^3	$< 18,927$	$< 3,785$
3	1,15	Wrong pin orientation	pins/batch	$< 10/300$	0
4	2	Pin presentation rate	seconds/pin	< 10	< 2
5	5	Number of bent/dulled pins	pins/batch	$< 10/300$	0
6	10	Volume of consecutive pin input	pins/input	> 5	> 300
7	4,12	Torque vibration resistance	gram-cm	> 130	> 325

The SI unit volumes listed in the Acceptable and Ideal categories roughly translate to 5 gallons and 1 gallon, respectively. The Acceptable pin orientation failure rate is dictated by Melanie’s estimate that she currently pokes herself three times for every 150 pins that she grabs. The chosen torque resistance values were chosen in accordance with the Japanese Society of Precision Engineering [1], with an ideal value aligned with a safety factor of 2.5.

2.6 Project Management

The Gantt chart in Figure 7 gives an overview of the project schedule.

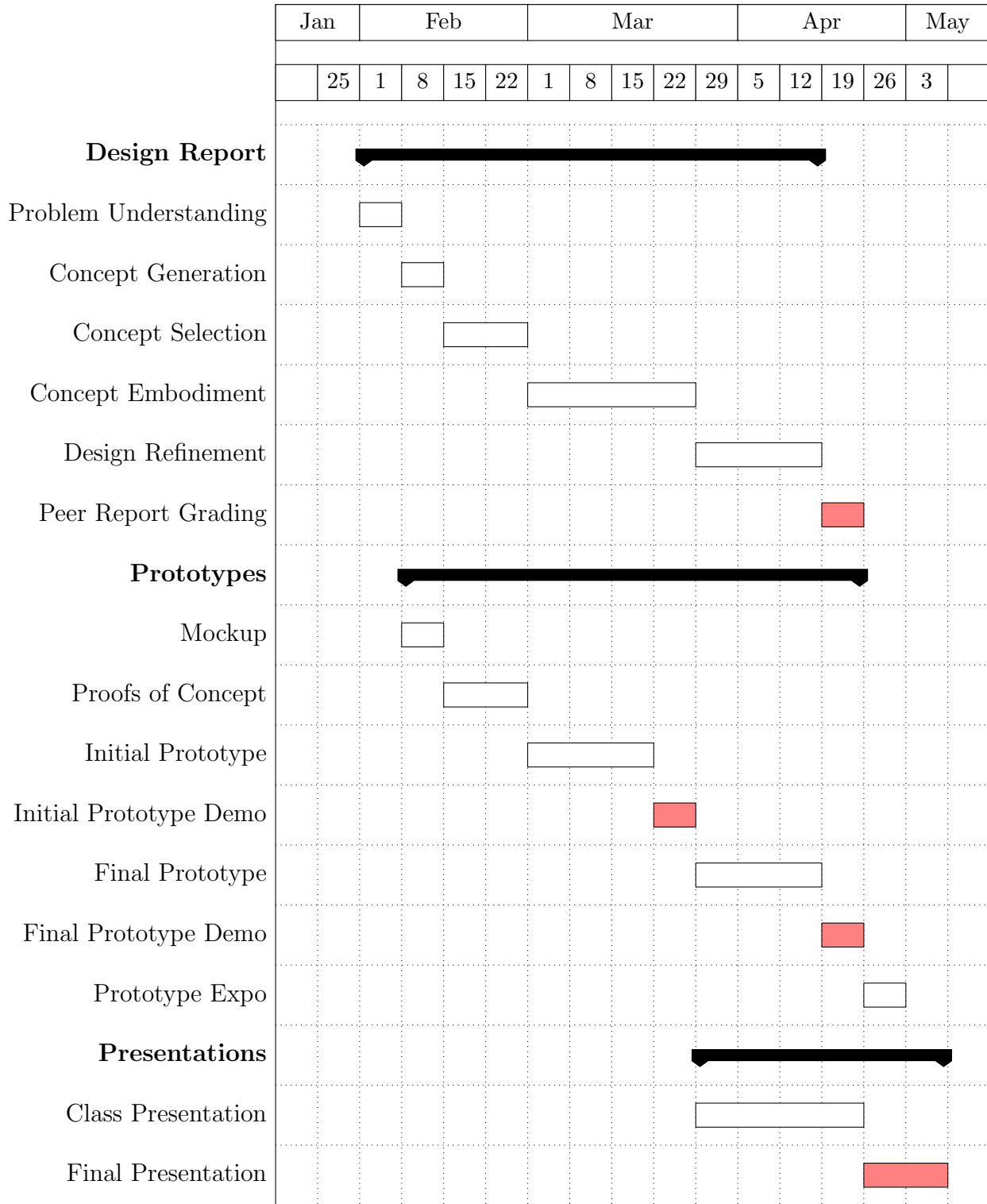


Figure 7: Gantt chart for design project

3 Concept Generation

3.1 Mock-Up Prototype

Our group created a mock-up based on one of our design concepts, titled "Funnel." The design concept is shown in Figure 8 below.

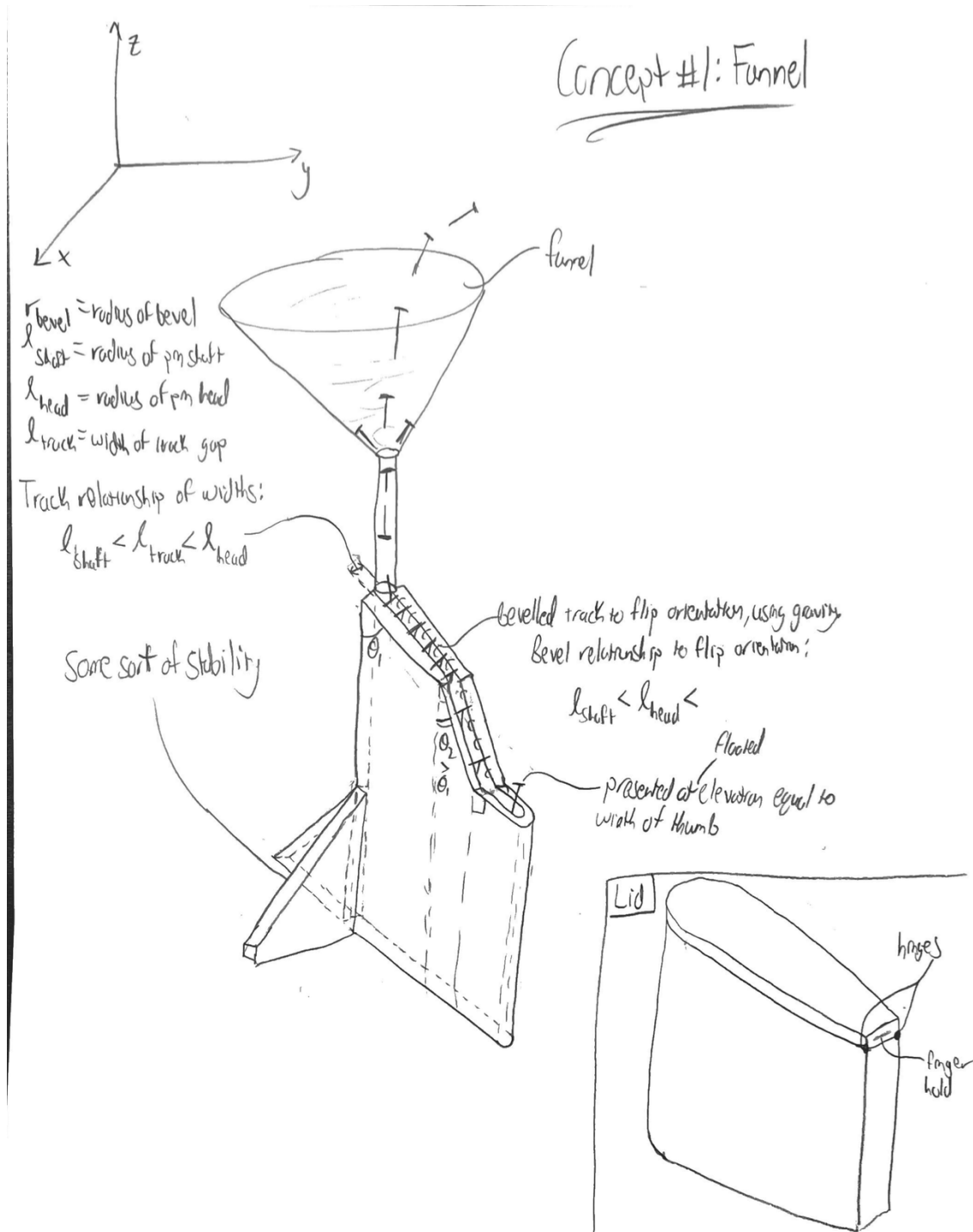


Figure 8: Funnel concept drawing

Observe that there are a few key design solutions highlighted in the Funnel mock-up design. First, the funnel receives and stores a large number of pins at the top end shaped like a funnel. The bottom of this funnel has a hatch which is activated by the user, letting through new pins into a vertical passageway, and onto the exterior conveyor hill. The downward slope of the pin conveyor allows the pins to fall to the presentation ending of the conveyor simply with gravity. Also, the conveyor track is bevelled such that the pins will automatically rotate and fall heads up when coming from the passageway. Finally, there will be a second, simultaneously-activated hatch at the bottom of the conveyor hill, which will open and let through one new pin to be presented to the user. Wide-shot, profile, and detail images of our mock-up for the Funnel concept are shown in Figures 9, 10, and 11 below.

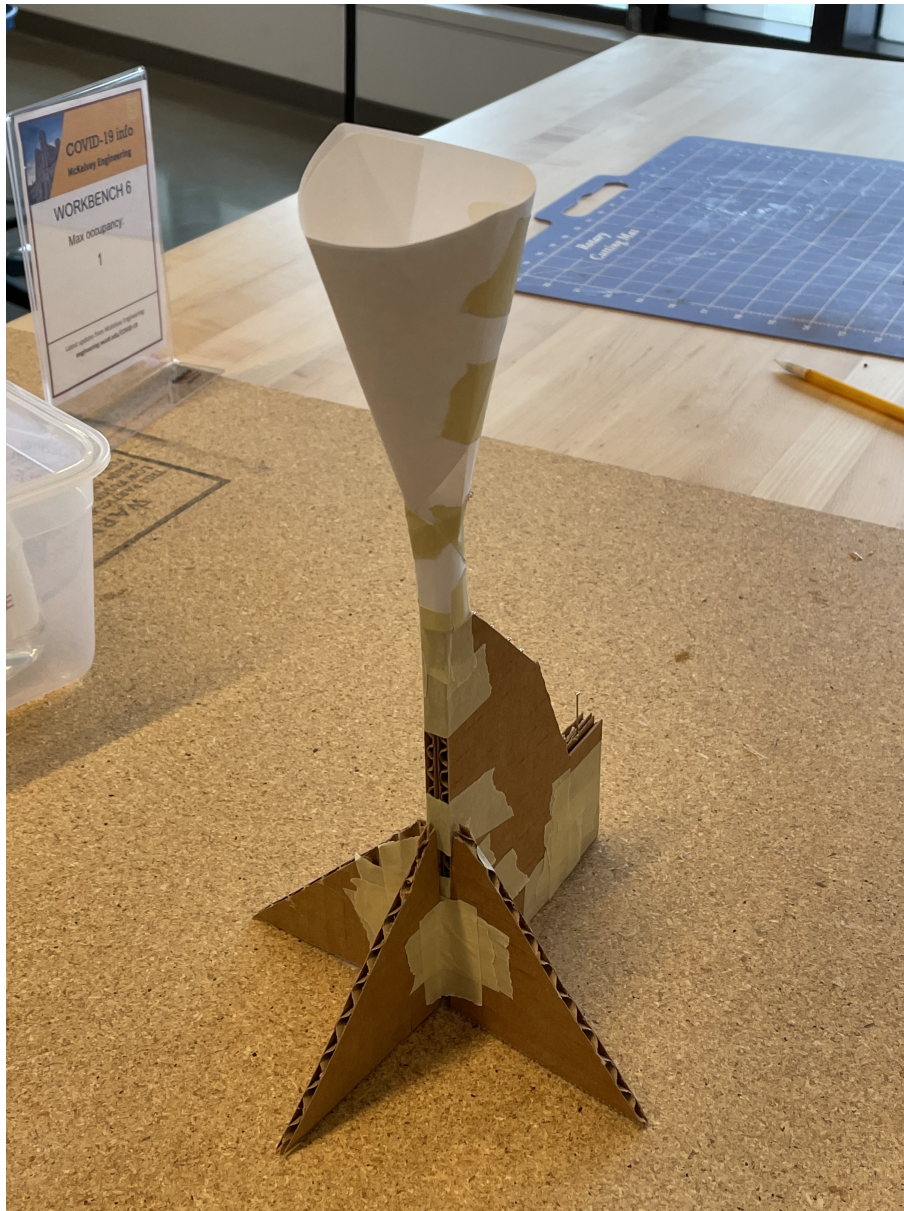


Figure 9: Funnel mock-up



Figure 10: Profile view of Funnel mock-up

Note that in the following detail image in Figure 11, the last pin that has made it past the last hatch is floated above the conveyor track. This allows the user enough vertical space to fit their index finger and thumb on the pin shaft to pick it up comfortably.

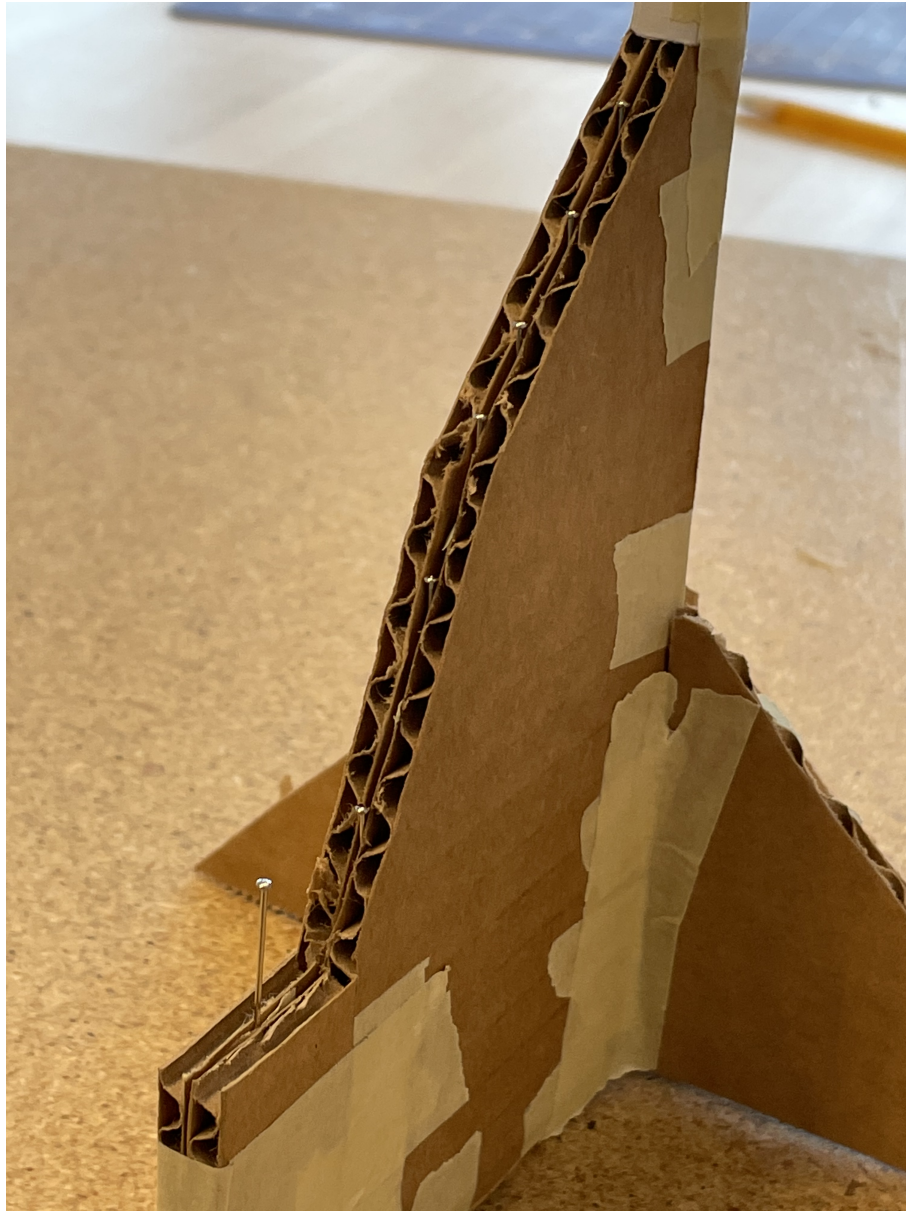


Figure 11: Detail of mock-up pin conveyor hill

After building the mock-up, we highlighted a few benefits and shortcomings of the design. The first benefit of the design is that the pin conveyor is driven by gravity. Also, the funnel acts as both a receptor and storage device for the pins. In addition, the bevelled, symmetrical track shape would be easy to construct with 3D printing or wood. There are a few shortcomings of the design, though. For one, there is no current way for the user to summon a pin and open the hatches. This may be solved with a mechanical finger plunger, similar to the one used in the Pintastic design shown earlier. Also, the conveyor hatches may let in more than one pin at a time, which would conflict with the one-pin goal of our dispenser. Overall, we believe that this mock-up covers many of the design needs laid out earlier in the report, and hope to build on these design benefits moving forward.

3.2 Functional Decomposition

Based on our preliminary research outlined in the Problem Understanding section, we have outlined a handful of important sub-functions that our pin dispenser should perform in order to meet our customer needs. These sub-functions are categorized and associated with a design solution, each of which is independent. This functional decomposition of our design is illustrated in a function tree in Figure 12 below.

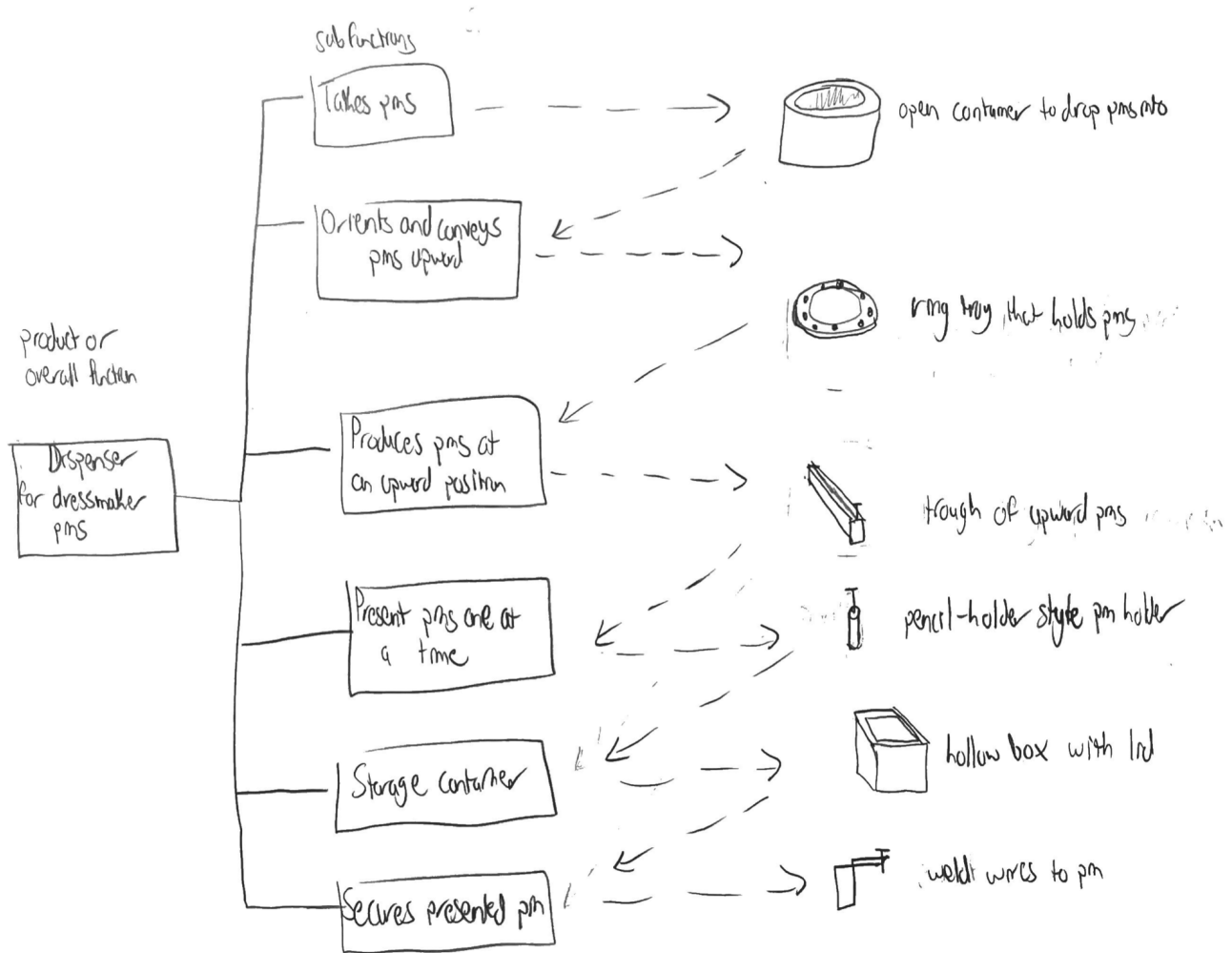


Figure 12: Function tree for Pin Dispenser, hand-drawn and scanned

3.3 Morphological Chart

Once our group established some independent sub-functions for the pin dispenser design, we started to populate our design options for each with a morphological chart, shown in Figure 13 below. Note that this chart highlights sixteen independent functional features that may be referenced in our design concepts moving forward, particularly in the subsequent Alternative Design Concepts subsection.









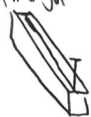








Takes pins	Cup 	funnel 	hole in container 	robot arm 
Orients and conveys pins upward	ring w/ holes 	belt-driven 	grips/magnets at top 	teardrop funnel 
Produces pins in an upward position	slim trough 	T-shaped conveyor 	downward track 	
Present pins one at a time	pen holder 	magnetic sliding door 	finger-controlled dispenser 	
Storage Container	hollow box 	magnetic lid 	bracket 	

Figure 13: Morphological Chart for Pin Dispenser

3.4 Alternative Design Concepts

3.4.1 Drum Sorter (Enrico Milletti)

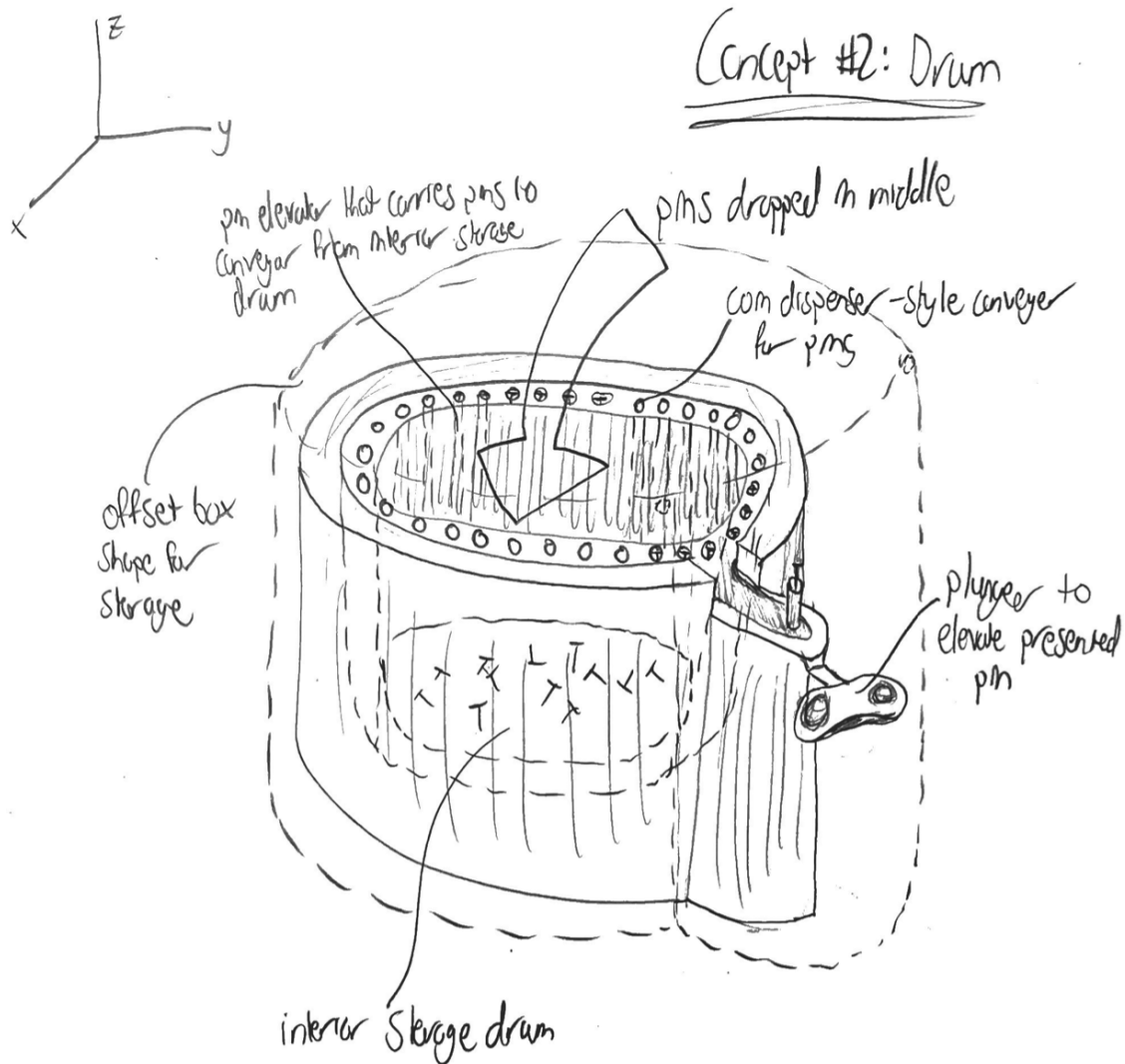


Figure 14: Preliminary sketch of drum sorter concept

Description: Once the storage container is removed and set aside, new pins are dropped into the open, central cavity of the drum. The bottom of the drum cavity is rotates with holes along the bottom edge, similar to a coin dispenser conveyor design. Once a pin spins and falls into a hole, a magnetic conveyor moves the pin to the top conveyor ring. Finally, with pins at the top ring, the user presses the plunger that rotates the ring and drops the foremost pin onto the presentation platform and elevates it for appropriate finger-grip placement. The user picks up the new individual pin from the platform.

3.4.2 Another Concept (Adrian Odamtten)

Concept # 2 , The rotator-inator

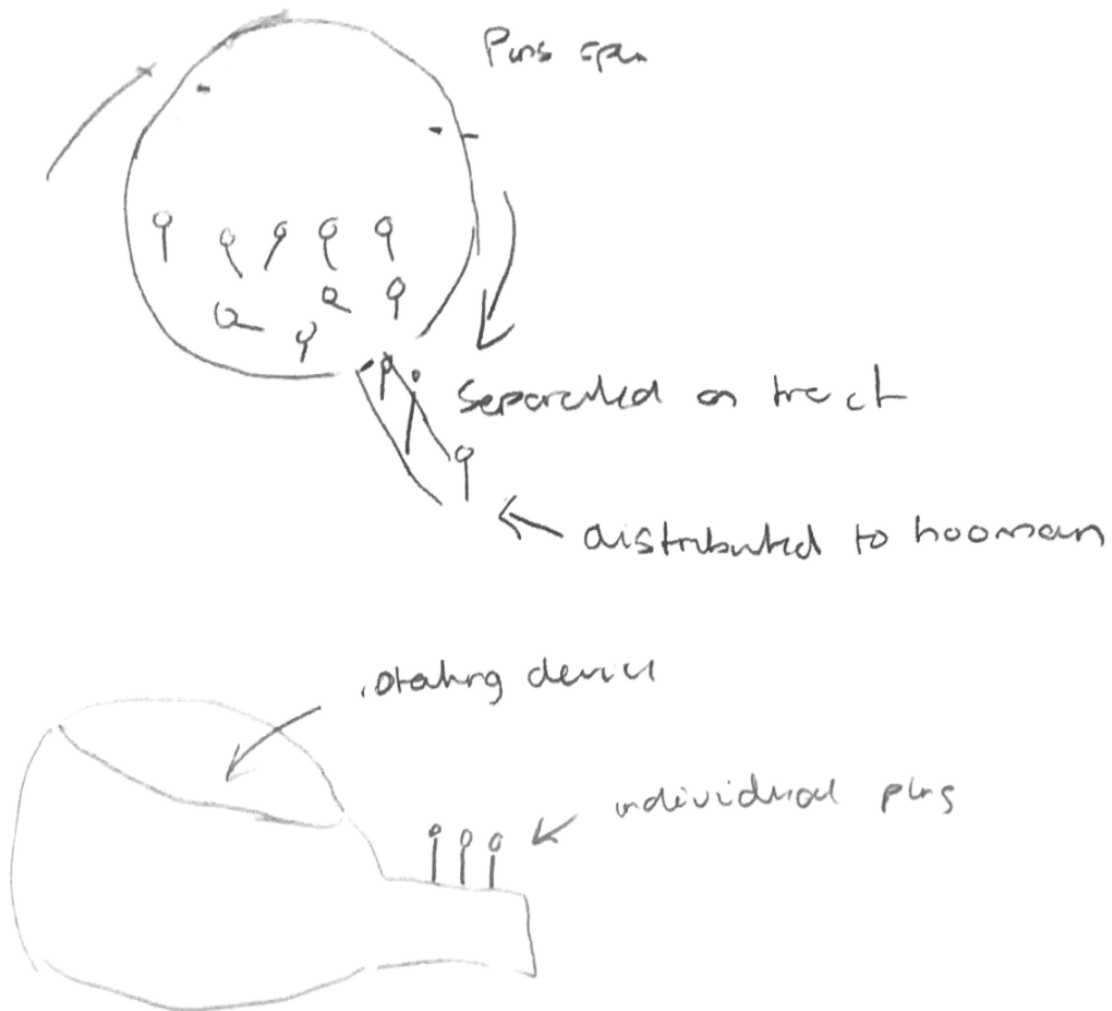


Figure 15: Final sketches of Robotic Arm concept

Description: The pins are rotated inside the device allowing them to reorient themselves in a vertical fashion on a track. The track is a line of holes perforated to the average pin diameter. The rotation of the device is controlled by a simple battery-operated DC motor while the motion of the track is user operated.

3.4.3 Cylindrical Sorter (Chad Picerni)

Concept #1: Rotating Cylinder with opening (small rim)

-Challenges:

- causing pin to drop accurately
- separating pins inside cylinder

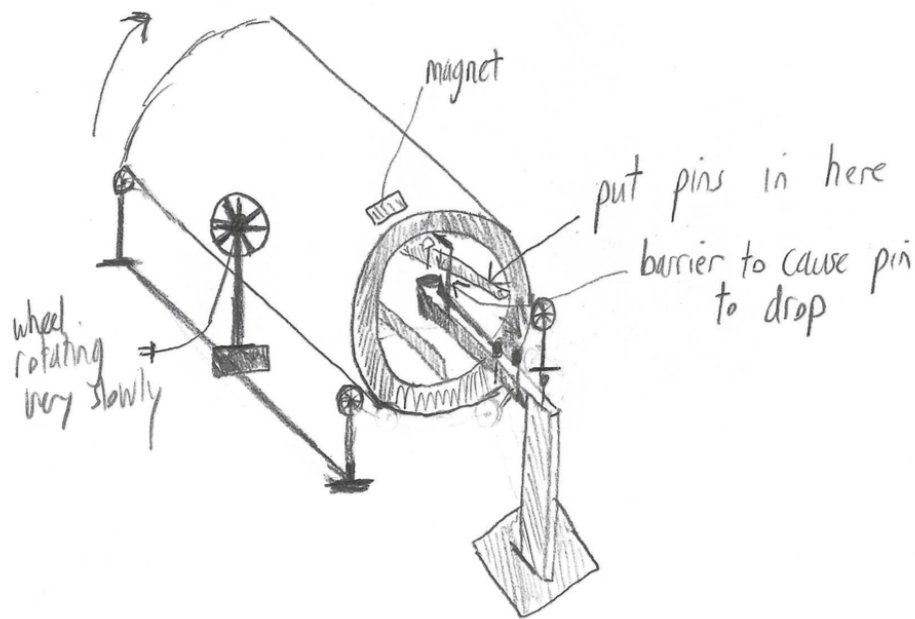


Figure 16: Preliminary sketch of rotating cylinder concept

Description: A hollow, cylindrical container is spun around very slowly using a device with a wheel attached to it. Pins are accepted only through the front of the container, and are secured within due to a clear, plastic rim formed around the opening of the cylinder. Once pins are inside, they are tumbled and untangled from each other due to four fins that span the entire length of the storage unit within the cylinder, removing large clumps of pins in the process. A magnet is placed on the outside of the cylinder, and has enough magnetic energy to carry one or multiple pins to the top of the cylinder. Once there, one pin will drop into a funnel upright due to a barrier stopping the pin from going back down the other side of the cylinder and will slide down a track that will allow the user to pick up a dispensed pin without fear of stabbing themselves.

3.4.4 Yet Another Concept (Edric Choi)

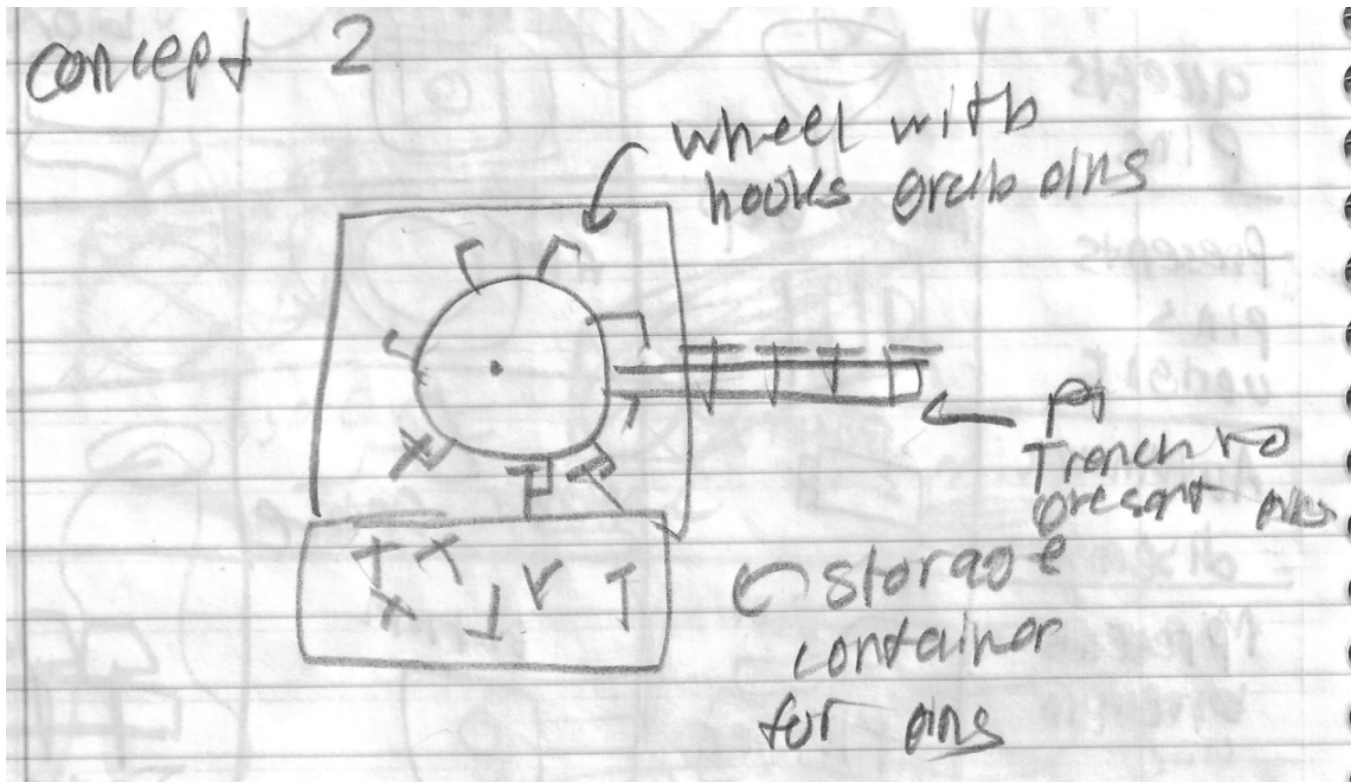


Figure 17: Final sketches of Robotic Arm concept

Description: A storage container sits at the bottom of the device which holds the pins. This box can be pulled in and out for ease of use. Slightly above the container is a rotating wheel with a series of hooks on it. As the wheel turns the hooks will scoop into the container and grab a pin carrying it to a trough where the pin can slide out and be presented for use. The wheel will keep spinning until the user turns off the machine with a button or switch.

4 Concept Selection

4.1 Selection Criteria

Our group utilized an Analytic Hierarchy Process to begin to determine the weighted importance of solving each criterion. The criteria we selected include upward sorting, pin rate, reception, securing pins, and stability. The results of the AHP are shown in Figure 18 below.

	Upward Sorting	Pin Rate	Reception	Secures Pins	Stable			
Upward Sorting	1.00	3.00	3.00	5.00	5.00	Row Total	Weight Value	Weight (%)
Pin Rate	0.33	1.00	1.00	3.00	3.00	17.00	0.42	41.73
Reception	0.33	1.00	1.00	3.00	3.00	8.33	0.20	20.46
Secures Pins	0.20	0.33	0.33	1.00	3.00	8.33	0.20	20.46
Stable	0.20	0.33	0.33	0.33	1.00	4.87	0.12	11.95
Column Total:						2.20	0.05	5.40
						40.73	1.00	100.00

ONLY change the lower-left triangle of the matrix
The right 3 columns will be automatically calculated

Figure 18: Analytic Hierarchy Process (AHP) to determine scoring matrix weights

4.2 Concept Evaluation

Using the criteria weights found in the AHS, we then used a Weighted Scoring Matrix to provide some numerical value for each alternative design concept's ability to address our customer's design needs. The results of the WSM are shown in Figure 19 below.

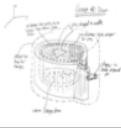
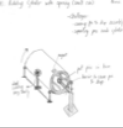
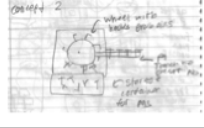

Alternative Design Concepts		Drum Sorter		Cylinder		Wheel		Rotator	
									
Selection Criterion	Weight (%)	Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted
Upward Sorting	41.73	3	1.25	4	1.67	4	1.67	3	1.25
Pin Rate	20.46	5	1.02	4	0.82	3	0.61	4	0.82
Reception	20.46	5	1.02	4	0.82	4	0.82	2	0.41
Secures pins	11.95	3	0.36	3	0.36	4	0.48	4	0.48
Stable	5.40	4	0.22	5	0.27	4	0.22	3	0.16
	Total score	3.872		3.935		3.795		3.120	
	Rank	2		1		3		4	

Figure 19: Weighted Scoring Matrix (WSM) for choosing between alternative concepts

4.3 Evaluation Results

For the AHP, we observe that the upward sorting criterion comes out as the most important by a noticeable margin. This is expected, since upward sorting is critical to user safety and operational success for the pins dispenser design. Furthermore, the pin rate and reception capability end up with equal weighting, which is understandable considering they are both operationally beneficial, but not critical to performance or user safety. Finally, the pin security and stability fall to the last two weight values, since they are simply preferred by the user but are in no way critical to performance or safety.

As for the WSM, we observe that the Cylinder concept garnered the highest rating, with the drum sorter and wheel designs closely behind. The significance of this result is important, though not absolute. We will move forward drawing beneficial design features from each design concept, but aim to utilize the wheel design at the core of the pin dispenser design. Specifically, we will attempt to integrate the sorting process from the wheel design, into the overall cylinder design.

4.4 Engineering Models/Relationships

4.4.1 Model 1: Force to Bend Dressmaker Pins

Our customer was interested in the delicacy with which our dispenser will handle her pins, since they “bend really easily,” in her words. The dressmaker pins have a shaft and head, with diameters that we denote as d and D , respectively. Assumedly, $d < D$, since the purpose of the pin head is to secure the fabric surrounding the shaft with a larger-diameter surface area. The most common scenario for a force to act upon a pin is with a mechanism that picks the pins up by the head in order to sort them, and places them into a track bottom-first. Therefore, we assume that the pin is a cylindrical cantilever beam, with a point force acting normal to the propagation of the beam at the head such that the bottom is fixed. Now, the bending stress equation for a cantilever beam is as follows:

$$\sigma = \frac{M * y}{I} \quad (1)$$

Where M is the calculated bending moment, which in this case is the force exerted by the sorting mechanism times the total length of the pin, which we notate as $M = F_{sort} * l$. Note that y represents the vertical distance from the neutral axis of the pin where the force is exerted on the pin, which is the shaft diameter D . Finally, since the pin is a cylindrical beam, we can simplify the moment of inertia, I , as $I = \frac{\pi d^4}{64}$. Therefore, we can re-write the previous equation as:

$$\sigma = \frac{64F_{sort}lD}{\pi d^4} \quad (2)$$

Therefore, we have established a relationship between the operational force exerted on pins, the pin dimensions, and the bending stress which can be substituted for yield strength purposes.

4.4.2 Model 2: Angular speed

In our design we plan on incorporating some rotating parts. One potential example would be the use of a wheel to carry our pins to our dispenser. However we obviously do not want the wheel spinning too fast, as that may damage the pins and cause our device to rattle and make a lot of noise. At the same time, we also want it to spin fast enough so that the pins are able to be dispensed at a steady rate. Therefore, assuming that we are dealing with a circle, we can use the equation below.

$$\omega = \frac{\Delta\theta}{\Delta t} \quad (3)$$

Here ω is our angular velocity, θ is our change in angular rotation, and t is the duration in time. Using this formula, we can calculate how fast our wheel needs to rotate in order to attain an optimal angular velocity.

4.4.3 Model 3: Power

Our design will have rotating parts, however this means we will need to pick a motor to rotate these parts. Care must be taken in choosing our motor, since picking one that is much more powerful than necessary will only add unnecessary weight and heat generation, not to mention it will use a lot more power. However, picking a motor that is too weak will result in our parts not spinning as fast as we want them to. Therefore, we can calculate roughly how much power our motor needs with the equation below.

$$P = \frac{2\pi * RPM * T}{60} \quad (4)$$

Here P is our power in Kw, RPM is our rotational speed and T is torque in N*m. With this equation we can see how much power a motor needs, at a given speed and torque, to select one accordingly.

5 Concept Embodiment

5.1 Initial Embodiment

Given the evaluation results from earlier in the report, we chose to move forward with the cylinder design for the basis of our initial concept embodiment. Shown below are images of the CAD model for our embodiment. In this design, four wheels are raised and connected to the support structure of the main cylinder body. The user cranks a handle that then rotates these wheels, and then these

wheels rotate the cylinder itself. Observe that the user feeds their pins into the open end of the cylinder, which sorts the pins with four wooden fins that are rotating along with the cylinder. Once the pins are de-clumped and oriented parallel with the fins, a magnet located on the interior wall of the cylinder traps a pin. This magnetic part of the interior wall rotates along with the cylinder until it runs into a stationary hook that drops the pins and places it into the dispenser track. The track brings the resulting row of pins forward to the front, whereby a pin can be taken by the user for sewing.

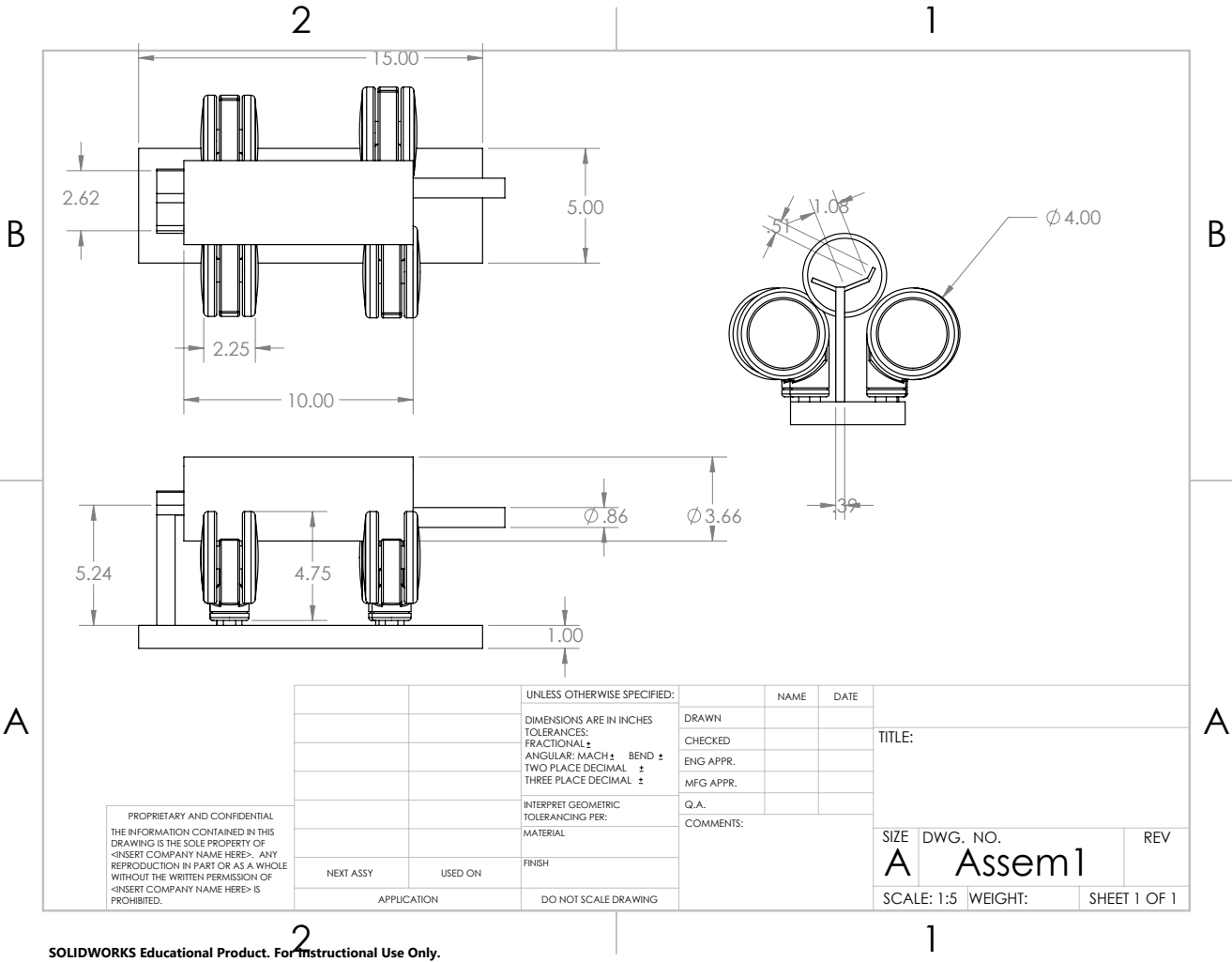


Figure 20: Assembled projected views with overall dimensions

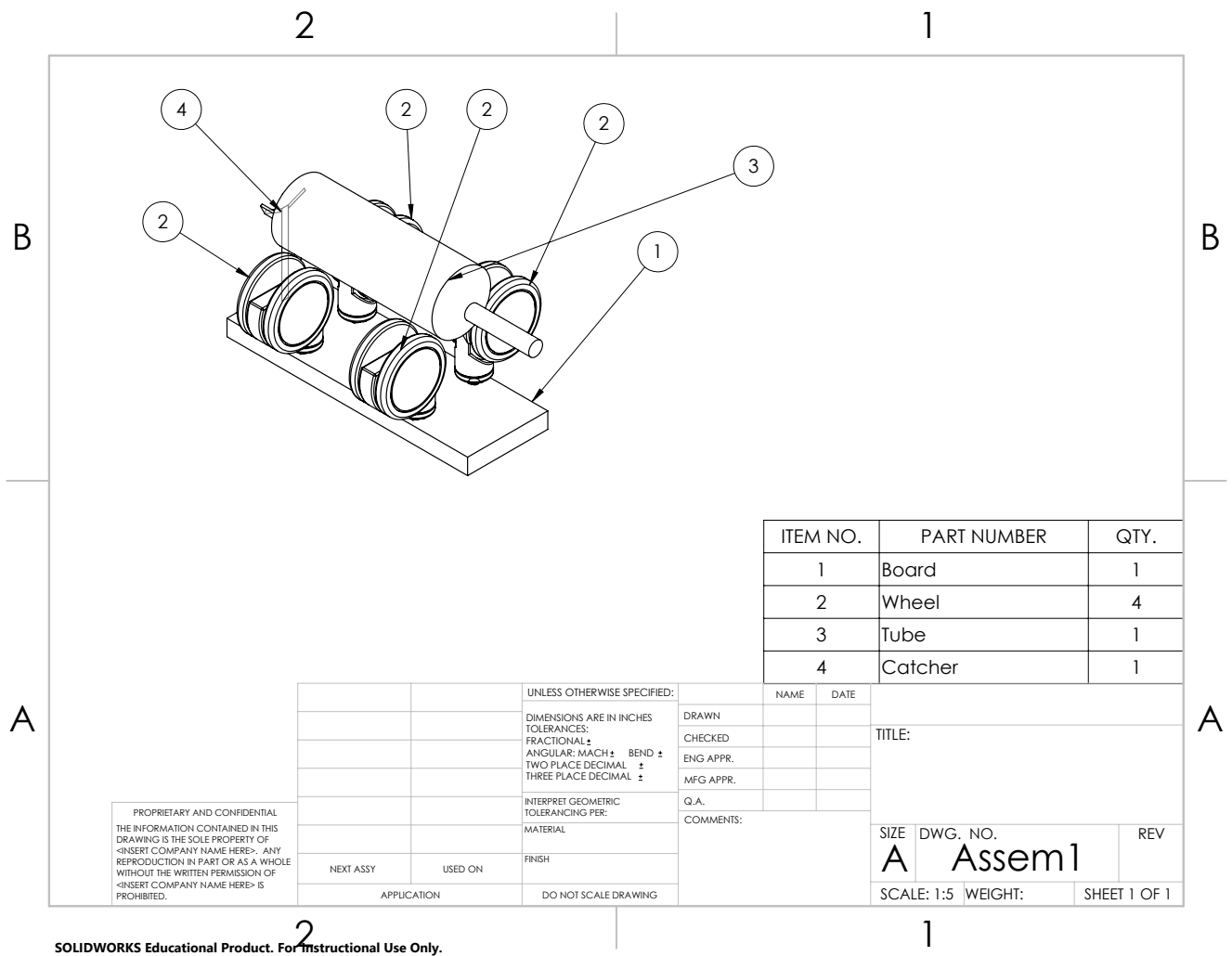


Figure 21: Assembled isometric view with bill of materials (BOM)

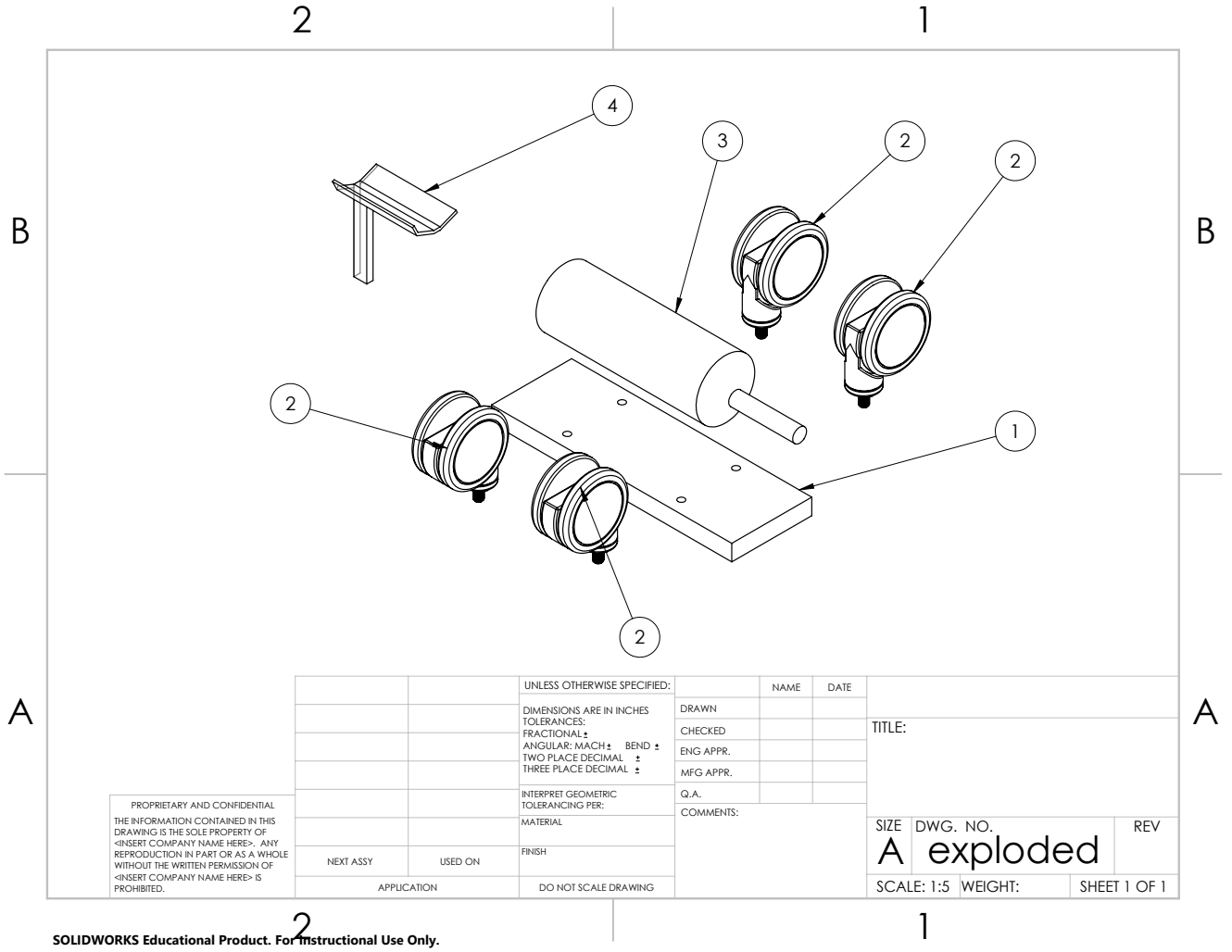


Figure 22: Exploded view with BOM reference

5.2 Proofs-of-Concept

As shown and discussed above, there are a few distinct parts in our design that we must analyze analytically. First, we note that the stationary barrier that knocks pins off of the magnet exerts an impact force on the pins. As discussed in our engineering models section earlier, this impact force cannot bend the pins, since bent pins are unusable for sewing. Returning to the derived impact stress equation:

$$\sigma = \frac{64F_{sort}lD}{\pi d^4} \quad (5)$$

We recall that the Dritz dressmaker pins, the pins of interest in our user study, are made out of nickel-plated steel [2]. The yield stress of steel is approximately 350 MPa [3], and the dimensions of the pins are as follows: $l = 0.0269875m$, $D = 1mm$, and $d = 0.5mm$. Plugging in these values for the dressmaker pin properties, we get a value for the impact force that will cause bending in the pins:

$$F_{sort} = \frac{\pi \omega d^4}{64lD} = \frac{(\pi)(350e6Pa)0.0005m^4}{64(0.0269875m)(0.001m)} = 0.04N \quad (6)$$

Next, we assume a generous factor of safety of 2.5, such that the effective bending force that can bend the dress maker pins is $F_{bend} = F_{sort}/FOS = 0.04N/2.5 = 0.016N$. Plugging in this benchmark impact force, the radius of the cylinder, $r = 1.5in = 0.00508m$, and the mass of the barrier hook $m = 20g = 0.02kg$ into the centripetal force equation, we solve for the allowable rotational velocity that the servo motor can rotate the cylinder at:

$$F_r = m\omega^2 r \quad (7)$$

$$\omega_{bend} = \sqrt{\frac{F_{bend}}{mr}} = \sqrt{\frac{0.016N}{(0.02kg)(0.00508m)}} = 12.5rad/s = 120RPM \quad (8)$$

Therefore, in order for the pins to not get bent when hitting the stationary barrier that places them on the track, the motor cannot crank the wheels and cylinder shell faster than approximately 120 RPM. Yet, we observe that this benchmark for rotational speed is extremely fast to rotate an entire cylinder shell at, so even with a factor of safety of 2.5, the barrier impact force on the pins would not come realistically close to a value that bends them. As a result, we will cap the operational speed of the servo motor at 120 RPM in our next prototype.

Drawing from the concept selection process discussed earlier in the report, we have identified three main performance goals for our proof-of-concept model. These goals are: The device dispenses at least one pin every three seconds, the device dispenses pins in the correct, upward orientation at least 90% of the time, and the device can accept at least 50 pins at once. In order to test these performance goals, we built a proof-of-concept dispenser, shown in Figure 24 below.

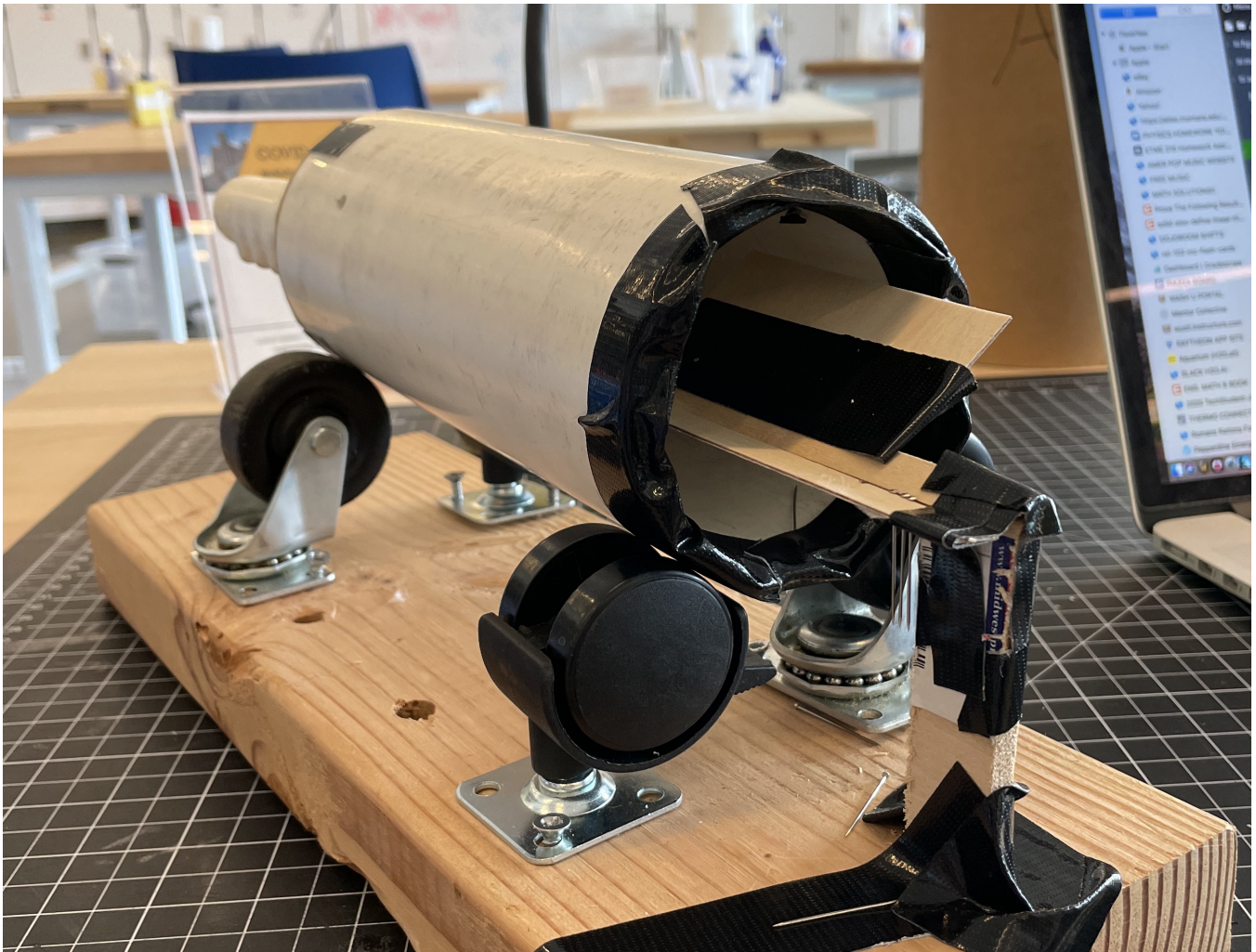


Figure 23: Proof-of-concept prototype

Note that the design plan was modified in our proof-of-concept iteration, such that a servo motor was replaced with a bike handle. We did this in order to simplify the rotational functionality of our design to isolate and test the performance goal that states our dispenser must dispense at least one pin every three seconds. Also, we taped most of the components together for convenient construction in order to simply test our performance goals. In the future prototype construction, we aim to use more permanent, stable connection methods including epoxy and screws. Observe that the proof-of concept prototype is otherwise fairly close to the CAD model concept embodiment plan laid out earlier.

We far exceeded the first performance goal that states our dispenser must hold at least fifty pins at a time, since the cylindrical PVC housing was far larger than the box of 750 pins that we used and stored for practice in our tests. As shown in Figure ?? below, we simply had to pick up the cylinder, drop the batch of pins into the cavity, and the pins fell to the back interior wall of the cylinder. Since Melanie had said earlier that a sewer rarely uses more than 250-300 pins at a time, we believe that this capacity is successful in retaining the pins that a sewer would use and store in practice.



Figure 24: Successful pin storage demonstration with proof-of-concept

Then, for the performance goal that states the dispenser must dispense the pins at an upward orientation for at least 90% of all pins dispensed. As shown in Figure 25 below, the catcher at the front of the dispenser is designed appropriately for this feature, and we observe that the pins fell into the front conveyor track every time a pin had successfully dropped down from the magnet. Yet, the main problem we had with this catching process was that the wheel foundation system as a whole was not stable enough consistent transaction between magnet and catcher. Therefore, in our final prototype design, we hope to stabilize the system with fasteners that restrict the rotation of the cylinder uni-axially, such that the cylinder will not bump around or fall off of the wheels entirely. Otherwise, we were entirely successful with dispensing pins in an upward rotation when we stabilized this transaction between magnet and catcher.



Figure 25: Demonstration of upward pin orientation with proof-of-concept

Finally, the proof-of-concept dispenser did not meet the last performance goal to dispense at least one pin every 3 seconds. Instead, we had to feed pins to the magnet manually so that they could move from magnet to catcher. So, in order to achieve this goal in the future prototype design, we aim to implement a handful of additional features. First, we will add sorting fins that will selectively feed pins to the sorting magnet, such that the pins will be continuously fed to the front track at a rate proportional to the rotational speed of the servo motor, and of the cylinder in tow. Next, we will slant the front conveyor track so that the pins automatically slide to the front and presented at a certain speed that is dependent on the downward slope of the track. Finally, related to the upward orientation performance goal, we also hope to build a more complex track that has a lifted, lower interior track that presents pins as elevated so that the user can confidently grab the pin shaft itself with their index and thumb fingers.

6 Design Refinement

6.1 Model-Based Design Decisions

As mentioned before, the first component of interest that has an influence on the dispense and sorting rate for the dispenser is the rotational speed at which our servo motor operates at. We found the following benchmark in the previous section as shown below:

$$\omega_{bend} = \sqrt{\frac{F_{bend}}{mr}} = \sqrt{\frac{0.016N}{(0.02kg)(0.00508m)}} = 12.5rad/s = 120RPM \quad (9)$$

Such that our maximum rotational speed for the servo is $\omega_{bend} = 120$ RPM. We note that this

rotational speed benchmark is to avoid bending the pins when they hit the stationary sorting hook that places them on the front track. We also note that this benchmark was calculated with a safety factor of 2.5, which is conservative considering we will not realistically set the motor close to 120 RPM. this is due to the fact that, at high speeds, centrifugal force will take over and the pins will simple stick to the walls of the cylinder, rather than freely fall between fins for de-clumping.

Another component of interest in our dispenser design are the sorting fins inside of the main cylinder. We note that the fin's function is to slowly grab pins from the back wall of the cylinder after they are deposited, and then to de-clump and carry the pins along to the front of the cylinder, where they are finally placed on the front dispenser track. Related to this functionality, the fin's face must be flat enough that they can move pins along their face in a parallel direction, while it's cross-section must be thin enough that they will not obstruct pins from falling into their slot when rotated. These two features for sorting are illustrated in Figure 26 below.



Figure 26: Synthesis of conveyor and de-clumping functionalities for fins

We note that the optimal shape for the dispenser's fins is a thin, slightly-bevelled rectangular prism. This shape provides both the flat face to slide pins along to the front of the cylinder, along with an optimized cross section that does not obstruct pins from falling into the adjacent or opposite fin channels effectively.

Another component of the dispenser that we focus on in our design refinement is the front dispenser track's ergonomics for picking up pins. This is of course central to our main performance goal of correct orientation of dispensed pins, as failure to meet this goal results in user injury as well as inability to retrieve pins effectively. Therefore, we aim to adjust the design of the catcher at the front of the dispenser, which houses the conveyor track, such that the user can easily grab a pin with their fore finger and thumb. We assume that the effective surface area of a laterally-oriented thumb, which is of course larger than that of a fore finger, is approximately 0.5 inch. Note that this is not the whole surface area of the thumb at a lateral orientation, but instead the effective surface area of the thumb that the user actually needs to grab a pin with. So, since we want to reveal at least 0.5 inches of length of the pin's shaft to the user (assuming the width of the effective surface area is 1 inch such that $A_{eff} = 0.5inch = (1inch) * (0.5inch)$), we design the catcher to house at most $l_{eff} = l_{pin} - l_{lift} = 1.0625 - 0.5 = 0.5625$ inches. Therefore, we must place an interior, lifted track within the catcher track that can present the dispensed pins with enough exposed shaft length for the user to comfortably grab at reception. The lifted track design is illustrated in Figure 27 below.

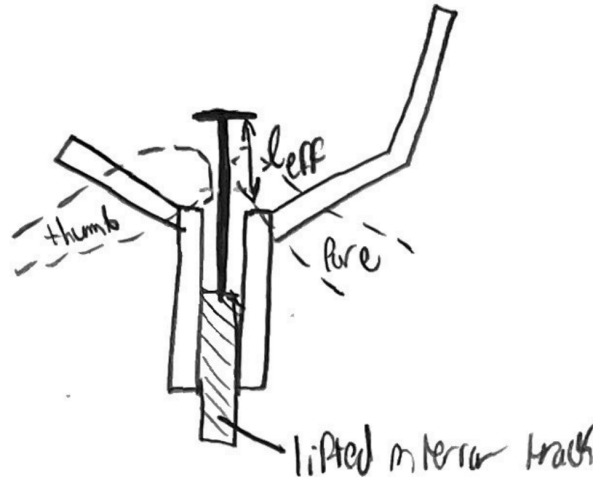


Figure 27: Cross-section of lifted interior track design for ergonomic pin reception

6.2 Design for Safety

Majority of our concerns about the safety of our device pertain to the presence of moving parts in our mechanism, and the sharp pins. As design engineers we tried to anticipate possible operational hazards in order to take mitigating steps.

6.2.1 Risk #1: Pin gets jammed in sliding mechanism

Description: During operation and due to the sheer number of pins in the vessel, it is possible that a pin could fall into the sliding mechanism. An accumulation of pins in the crevices of the slider could damage the ball bearings, and cause some pins to fly towards the user.

Severity: Catastrophic

Probability: Likely

Mitigating Steps: Fashion a cover for the slider such that any pins that fall will not enter its crevices.

6.2.2 Risk #2: User picks up a pin that is oriented head down

Description: The dispenser somehow delivers pins with the head facing the wrong direction. The user does not anticipate this, and accidentally pricks themselves on a pin.

Severity: Marginal

Probability: Seldom

Mitigating Steps: Ensure that the dispensing mechanism can only fit pins that have their heads facing in the correct direction. The "catcher" will have rails that are fitted to the diameter of the pin head.

6.2.3 Risk #3: User gets injured during storage and machine relocation

Description: The user forgets that the machine is not empty, and accidentally pours out the remaining pins onto herself, or on their valuables.

Severity: Negligible

Probability: Seldom

Mitigating Steps: We will fashion a lid that will allow the user to cover the tube after use. We will also provide steps for storage/relocation.

6.2.4 Risk #4: User injures themselves when loading the mechanism

Description: The user pricks themselves when handling the pins and transferring them into the vessel.

Severity: Marginal

Probability: Occasional

Mitigating Steps: The vessel has been made large enough such that the user does not have to touch the pins to load it at all. They simply have to pour in the pins from their original container.

6.2.5 Risk #5: Pins escape from rotating vessel

Description: A high angular velocity caused by an oversized motor would cause the machine to fly out tangentially and towards a user

Severity: Catastrophic

Probability: Unlikely

Mitigating Steps: We sized our motor such that the pins are never moving at high speeds.

The heat map from our risk assessment template is shown below:

		Probability that something will go wrong				
Severity of risk	Category	Frequent Likely to occur immediately or in a short period of time; expected to occur frequently	Likely Quite likely to occur in time	Occasional May occur in time	Seldom Not likely to occur but possible	Unlikely Unlikely to occur
	Catastrophic		Pin gets jammed in slider			Pins escape from rotating vessel
	Critical					
	Marginal			User injures themselves when loading the machine	User picks up a pin that is oriented head down	
	Negligible hazard presents a minimal threat to safety, health, and well-being of participants; trivial			User gets injured during storage and machine relocation		

Figure 28: Heat Map

Given our heat map, it seems that the pin getting jammed in the slider will be the highest priority risk. We must take steps to ensure that we decrease the likelihood of the pins getting caught in any of our moving parts. The slider is the moving part with the greatest cause for concern since the motor rotates the vessel relatively far from the vessel's entrance. The slider, however is positioned at the entrance of the vessel. The pin escaping from the rotating vessel is the next priority since this is the greatest concern for user safety. This would occur as a result of design error, rather than a human error. The user injuring themselves when loading the machine, and the user picking up a pin that is oriented head down are the next in terms of priority. These are both user errors which can be mitigated, but are also not too severe. The user injuring themselves during storage/relocation is the lowest priority risk because we do not foresee users routinely confronting this issue. We still take steps to further reduce the probability of its occurrence.

6.3 Design for Manufacturing

For our current design prototype, there are 8 parts and 4 threaded fasteners. The Theoretically Necessary Components (TNCs) are listed below:

- Foundation: Wooden plank with rubber dots on the bottom both provides structural stability for the remainder of the design and damping absorption for the sewing machine's strong vibration.
- Wheel: Four separate wheels are screwed to the wooden support plank previously discussed. The four total fasteners between the wheels and wooden plank are the only threaded fasteners

in the design, and are the result of pre-existing threaded fasteners in the bottom of the wheels that provide a strong structural connection. Since the wheels both rotate and provide stability to the cylinder, a strong connection to the support foundation is vital. Yet, a hypothetical consolidation of the wheels may provide manufacturing ease. Therefore, a hypothetical design solution to consolidate the wheels would be to construct a continuous rotational beam one each side that would provide additional rotational stability for the cylinder (due to increased surface contact area) and would necessitate two less fasteners. Figure 29 illustrates such a hypothetical wheel design. Yet, this continuous beam design would actually require more fabrication material than before, so it would not be financially advantageous, even if it were to marginally reduce the parts of parts and fasteners.

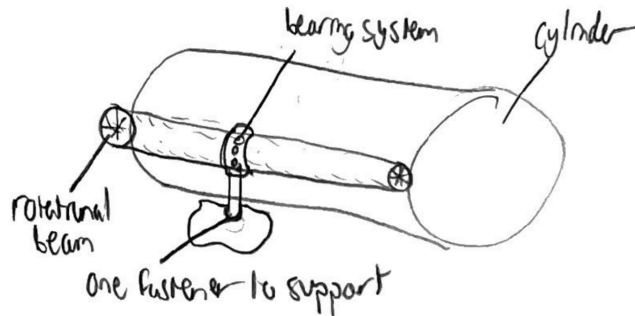


Figure 29: Alternative rotation beam design concept

- Cylinder Body: The central body consists of a PVC shell with one back wall, a glued bicycle handle, and four internal, glued wooden fins. Since the main material of this body is PVC, we used glue as opposed to threaded fasteners. Hypothetically, the whole cylinder body could be 3D printed or injection molded as one singular part, yet we were limited with print bed size for our school's 3D printer to actually produce this cylinder body system as one part.
- Catcher: The catcher consists of a few small boards of balsa wood that we glued and taped together for proof-of-concept demonstration of our design's pin conveyor functionality. Hypothetically, one 3D printed part would be an effective replacement for this current shoddy construction method, and we hope to consolidate this catcher part into one part for our final prototype. This consolidated design part is the same as in the CAD design shown above in the Concept Embodiment section. In addition, it would be helpful to keep the interior track for the catcher as a separate part that can detach, in case pins or extra fabric fall into the interior track and clog the passageway.
- Servo Motor: This part is bought off the shelf and is glued and taped to the bicycle handle to transfer the torque power to the cylinder body for rotation. As discussed in the Concept Embodiment section above, we have capped the rotational speed at 120 RPM and do not plan on running the servo considerably fast. The servo is of course a separate part from the bicycle handle and cannot be consolidated without an unnecessary amount of re-engineered design to use the rotational arm as a mechanical appendage to the servo's output shaft.

6.4 Design for Usability

Various factors would influence the usability of our device. We have considered a number of impairments and how they pertain to the function of our device. We then considered how we could improve the usability of the device such that it is accessible to people with or without these impairments.

6.4.1 Vision Impairment

Description: A user with impaired vision may not be able to discern the location or position of our switch. This would cause them to think that the machine is off when it is actually on, and vice versa. They also may not be able to discern between the elements of the machine which may require sequential operation such as the slider after pins have been caught. An idea would be to have clear labels and maybe even braille engraved on the machine. Another idea would be to provide sound cues for sequential steps.

6.4.2 Hearing Impairment

Description: Hearing impairments would result in users not knowing if the machine is running or not. This has the potential of being hazardous as they could try and load the vessel when the machine is already running. An idea would once again be clear labels, and a warning sign that lights up when the machine is in operation, and turns off when the machine turns off.

6.4.3 Physical Impairment

Description: Physical impairments would hinder a user who would want to feed pins into the vessel/turn the switch on and off. A pedal operated rotating mechanism would work for those who aren't able to use their hands. Adjusting the positioning of the vessel to being vertical would also make it easier for those who can't use their hands.

6.4.4 Control Impairment

Description: This could result in many hazards such as personal injury. An idea would be to place warnings on the device which state that an individual suffering from these ailments should not operate for excessive periods of time. Other than that, we could attempt to fully automate the pin dispensing process to mitigate user error and injury. At the push of a button the device would accept new pins from a box the user placed on the vessel, and then dispense them accordingly.

7 Final Prototype

7.1 Overview and Documentation

Following our design refinement, we have constructed a final prototype that meets all three of our performance goals. This final prototype is shown in Figure [30](#) below.

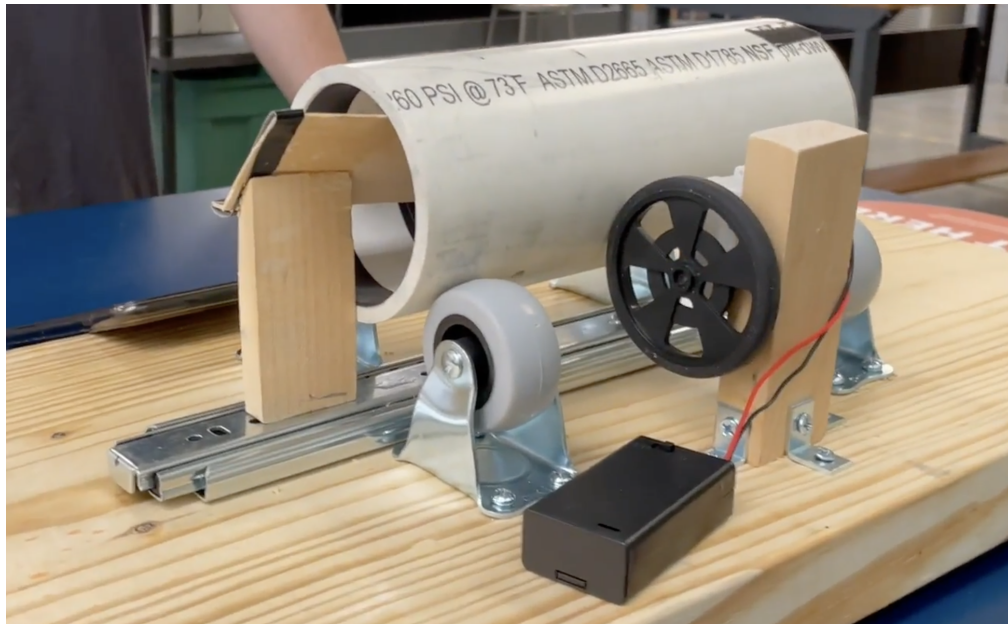


Figure 30: Image of final prototype

Note the differences between the initial prototype and the final prototype. First, we have replaced most of the taped fastening with super glue and threaded fasteners in order to create a more stable and permanent constructed system. Next, we have replaced the handle rotation with a servo motor that is connected to a large, rubber wheel that automatically rotates the central pipe container. This is highlighted in Figure 31 below. There is an internal battery system that can be replaced occasionally, removing the need for manual charging and rotation on the part of the user. Furthermore, we have refined the catcher system by constructing a metal track for the pipe container, such that the catcher can slide in and out of the pipe at will for storage or pin replacement. This track system is shown in Figure 32 below.

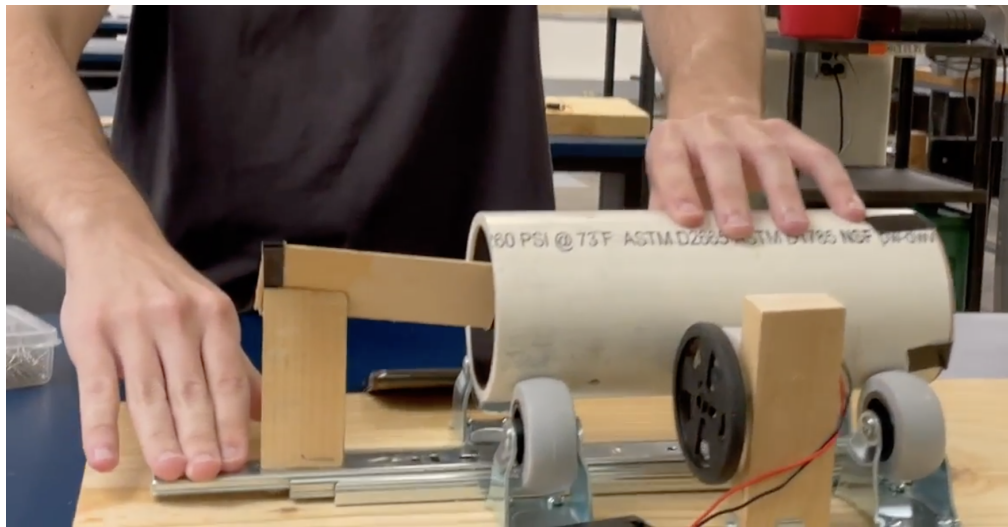


Figure 31: Highlight of motor-driven wheel rotation system

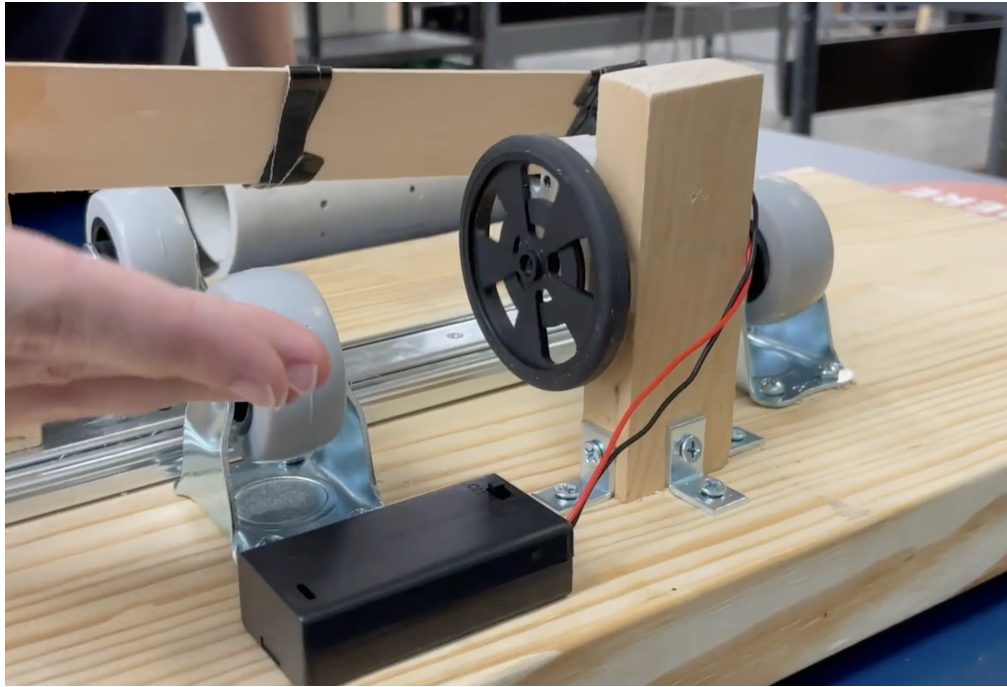


Figure 32: Highlight of catcher track system

Unfortunately, some pins still fall out of the current catcher occasionally, so we plan on adding a lower catcher platform that can pick these up. We also hope to add an additional "rumbler" motor that can shake pins into the catcher slot at a more consistent rate. Otherwise, we have met all of our performance goals and believe that our final automatic pin dispenser product may serve as a powerful tool for sewers to simultaneously handle garments and dressmaker pins effectively.

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